ISSN: 0973-4929, Vol. 18, No. (1) 2023, Pg. 18-29

Current World Environment

www.cwejournal.org

Environment and Health Impact of Solid Waste Management in Developing Countries: A Review

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Abstract

The subject of Solid Waste Management has attained global attention over recent years. This issue is observed to be more prominent in developing countries than in developed countries due to inadequate funds and resources. Solid waste generation, segregation practices, storage facilities, collection frequencies and disposal methods are evidenced to be unsustainable in developing countries. Uncontrolled dumping and open burning are common scenarios in these countries. Open dumping and burning of waste pose serious environmental and health risks. They have led to severe forms of air, water and soil pollution. Municipal Solid Waste pollution increases the mortality as well as morbidity of diseases. Thus, the present study reviews the environmental consequences and subsequent health jeopardies due to improper and inefficient Solid *Waste Management.* The study focuses more on environmental sustainability of Solid Waste Management than economic and social sustainability. Hence, a paradigm shift towards green and clean Solid Waste Management is vital as it safeguards the ecosystem while preserving a green economy and social equity amongst present and future generations.

Article History
Received: 05 September 2022
Accepted: 23 March 2023

Keywords
Environment Risks;
Health Risks;
Solid Waste Pollution.

Introduction

Municipal solid waste management (MSWM) is a prime issue worldwide.[1] MSWM is associated with challenges of increasing generation rates, poor disposal methods and environmental consequences.[2] These challenges are, however, more prominent in developing countries due to inadequate funds, obsolete technology and lack of institutional setups.[3] There are various aspects of MSWM ranging from goals, practices, strategies, control, regulation and monitoring of the production, financial aspects to environmental impact assessment of policies and sustainable alternatives.[4] These aspects should be integrated holistically to mitigate challenges arising from MSW, its management and processing treatments.

Sustainable development encompasses sustainable MSWM practices with reduced environmental emissions.[5] Sustainable MSWM has been one of

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Doi: http://dx.doi.org/10.12944/CWE.18.1.3

the chief environmental agendas in the 21st Century.[6] It has become a precondition for mitigating global ecological challenges. The MSWM is said to improve the quality of the environment, which is a prerequisite for per capita well-being.[7] In many countries, the development of waste plans and policies aiming at controlled dumping, improving disposal methods and reducing emissions have resulted from environmental concerns and considerations.[8] The Indian regulations of SWM Rules, 2016 proposed segregation, proper collection and transportation, 3 Rs- reuse, reduce and recycle, and scientific waste disposal as fundamental principles of managing waste.[9] Babaei *et al.* (2015) write that environmental repercussions of waste have driven the residents' Willingness to Pay and Recycle for improved MSWM.

Generally, MSWM strategies focus on aesthetics, health, environment, land use and economic concerns.[3] Since the 1990s, the prime focus has been moved to environmental apprehensions, particularly regarding climate change.[11,12] It has been reported that one of the leading crucial anthropogenic sources of GHGs emissions is improper disposal and treatment of MSW.[13] It is pertinent to conclude why the waste management sector focuses more on environmental than societal and economic sustainability. A paradigm shift to a green and clean environment is vital as it safeguards the ecosystem while preserving a green economy and social equity amongst present and future generations.[14]

The objective of the paper is to present a framework that helps in the understanding of inefficient SWM practices and their impact on the environment and public health. The study attempts to identify the poor practices of SWM with particular reference to developing countries. The study intends to report the environmental hazards and emissions associated with various Solid Waste Management (SWM) techniques. It further evaluates the multiple forms of waste streams, their improper disposal and resulting health risks. The associated environmental and health risks are presented in a tabular format. This representation consolidates the data thoroughly, makes the results more understandable and attracts the users of produced information. The objective is in a view to propose relevant policies and implement the appropriate strategies.

Material and Methods

The paper uses a desktop research method to collect and analyze relevant literature. The technique involves three stages. The first stage consists in defining and understanding the research problem. The paper aims to explore the detrimental consequences of improper SWM practices on the environment and public health in developing countries. The second stage involves the collection of relevant literature from online sources. The online sources cover a scope of grey literature, peer-reviewed articles, books, conference proceedings and various academic databases. The third stage involves compiling and presenting the literature in a systematic order. From the existing literature, the study highlights the significant implications and recommendations to improve SWM practices in developing countries.

Solid Waste Management in Developing Countries

In developing countries, open dumping and burning are observed to be common scenarios.[15] Government authorities and households heavily depend on these unscientific methods because they are convenient and cheapest ways of disposal involving no use of technology. These inefficient and unsustainable practices result in environmental contamination and public ill health.[16,17] The reported environmental impacts vis-à-vis unsustainable practices are air contamination, nuisance odours, GHG emissions, visual effects, surface and groundwater pollution and vectors of diseases.[18,19] Previous literature elicits leachate mismanagement and contamination, as are the major subsequent issues.[20] The situation worsens in slum areas, shanty dwellings and filthy hovels with dense populations.

Illegal Dumping of Solid Waste in Developing Countries

There are few studies showcasing the negative impacts of nearby landfill sites. A study showed that Banjul, Gambia's landfill site in densely populated areas negatively affects nearby residents. Smoke from burning waste, odour and nuisances affect the nearby residing population. The high composition of coliform and fecal matter pollutes the nearby water bodies.[21] In Phnom Penh, Cambodia, households burned and dumped about 635000 tons of MSW in 2015.[22] In Thailand, over 65% of the waste is

abandoned openly.[23] In Abuja, Nigeria, more than 25 thousand tonnes of solid waste was produced annually in 2010. As a result, four dump sites were closed in 2005 due to foul odours, burning waste and air pollution.[24] A study in Kodungaiyur and Perungudi reported methane emissions from landfill to be as high as 11.3 Gg per year and 9.1 Gg per year.[25] A study in Greece estimated 1.64 Mg per year of biogas production from Akrotiri landfill using the LandGEM model.[26] Abushammala *et al*[27] assessed the total methane emissions from all the landfills in Malaysia to be 318.8 Gg in 2009. Liu *et al*[28] estimated annual ozone formation and aerosol formation due to the presence of landfills to be 8.9 * 105 and 3.5 * 104 kg per year, respectively. The significant contributors of air pollution reported were Toulene, mesitylene and mixed xylene. Wenjing *et al*[29] characterized odour pollution caused by landfill in China. The major odour-causing compounds were aldehydes, ketones, alcohols, ethers, esters and Sulphur compounds.

Al Raisi[30] studied the dumpsite located at Mathkal, Kolkata. It has severely affected the quality of ground and drinking water. The leachate percolation from the dumpsite contains toxic metals (Cadmium, Manganese, lead, nickel, etc.) and high potency of chlorides, fluorides, ammoniacal nitrogen, chemical oxygen demand, biological oxygen demand and organic carbons. Ghosh *et al*[31] evaluated leachate composition from a landfill site in Delhi. He reported that leachate contained low concentrations of heavy metals but exceeding levels of carbon. The mixture of contaminants in leachate was observed to affect cytotoxicity and genotoxicity. Chaudhary *et al*[32] found an association between the Leachate Pollution Index and health risks in non-engineered and engineered landfills in Delhi. Parvin and Tareq[33] analyzed the impact of leachate contamination at four landfills in Bangladesh. The leachate produced showed higher concentrations of toxic metals above permissible limits, resulting in higher carcinogenic risks to local inhabitants. In Nothanburi, Thailand, Aendo *et al*[34] reported that the concentration of cadmium, chrome, mercury, lead and nickel were ten times above the limits of the drinking water as per WHO. In Tiruchirappalli, Tamil Nadu, Kanmani and Gandhimathi[35] analyzed that the leachate produced has the Chemical oxygen dissolved ranging from 29880 mg L to 45120 mg L. The calculated BOD/ COD ratio was found to be less than 0.1. Therefore, heavy metals in the soil samples indicate appreciable soil contamination by the leachate movement.

Open Burning of Solid Waste in Developing Countries

Open waste burning exaggerates the problem of open dumping waste.[36] The combustion of openly dumped waste generates toxic emissions causing a significant threat to public health.[37] Soil samples of the dumpsites in the India, Vietnam and Cambodia are detected with polychlorinated dibenzofurans (PCDFs), polychlorinated biphenyls (PCBs) and polychlorinated dibenzo–p- dioxins (PCDDs), etc.[38]

Open dumpsites of Palembang and Surabaya have concentrations of PCDDs/PCDFs and PCBs ranging from 61000 to 310000 $fg_{TEQ}\ g^{-1}$ and 6300 to 32000 $fg_{TEQ}\ g^{-1}$.[39,40] Wang *et al*[41] assessed emission of toxic heavy metals from the open burning of MSW in China. They concluded that emissions are highly concentrated in developed and densely populated areas. Das *et al*[42] estimated air pollutants emission from open burning of waste in Nepal as 11900 tons of CO_2, 30 tons of CH_4, 630 tons of CO, 5.7 tons of NH_3, 5.0 tons SO_2 and 19.2 tons of NO_x. Pansuk *et al*[43] calculated 19.6 kt/year, 7.4 kt/year, 1.2 kt/year, 103 kt per year and 1247.3 kt per year of CO_2 CO, SO_2, NOX and particulate matter emissions from burning of solid waste respectively in Thailand. Kumari *et al*[44] projected carbon monoxide, sulfur oxides, dioxins, furans, nitrogen oxides, benzene, 1- hexane, toluene and ethyl benzene emissions using Intergovernmental Panel on Climate Change (IPCC). They concluded that metropolitan cities are more vulnerable to emissions than other cities in India. Okedere *et al*[45] estimated inorganic emissions, particulate matter, nitrogen oxides, Sulphur dioxide and methane emissions from open burning of waste to be as high as 81600 tons per year (TPY), 428400 TPY, 30600 TPY, 5100 TPY and 66300 TPY respectively in Nigeria. Park *et al*[46] calculated average annual emissions from burning of domestic waste to be 71 tons, 914 Kgs and 67 Kgs of particulate matter, heavy metals and polycyclic aromatic hydrocarbons (PAHs), respectively. Elehinafe *et al*[47] assessed the release of volatile organic compounds (64000 tons), polycyclic aromatic hydrocarbons (988 tons) and polychlorinated biphenyls (43 tons) from open burning of Municipal waste in the southwest region

of Nigeria. The case study of Huejulta, Mexico, shows that carbon dioxide equivalents emitted from Black Carbons (due to open burning) were 15 times more than the potential of methane released from the equivalent amount of organic decomposition of waste.[48] Therefore, the previous review indicates that waste burning should be prohibited and substituted with more sustainable alternatives.

Table 1: Environmental repercussions of SWM

Environmental impact	Contaminants / Pollutants	MSWM technique	Source
Air pollution	Gaseous emissions such as methane, carbon dioxide, nitrous oxides	Landfill	Talaiekhozani & Rezania,[49] Fisher *et al*[50]
Water Pollution	Leachates having a high content of ammonium, nitrogen, chloride, carbon and phenols	Landfill	Norouzi *et al*,[51] Mishra *et al*,[52] Han *et al*[53]
Soil Pollution	Heavy metals: cadmium, lead, copper, mercury, zinc and iron	Landfill	Milad,[54] Maurya *et al*,[55] Uma *et al*,[56] Vijayalakshmi *et al*[57]
Global Warming	Gaseous emissions such as carbon dioxide, carbon monoxide, nitrogen oxides, nitrous oxide and methane	Unsanitary landfilling, Backyard burning, anaerobic digestion and incineration	Nyika *et al*,[58] Saadatlu *et al*[59]
Ozone layer depletion	Nitrogen oxides, Ethylene, Cholorofloro Carbons	Landfilling, Backyard Burning	Wang *et al*[60]
Nuisance odour	Fungi & Bacteria bioaerosols	Composting, Landfilling	Wisniewska *et al*[61]
Explosion hazards	Gaseous emissions such as hydrogen and methane	Landfill	Karthikeyan *et al*[62]
Air acidification	Nitrogen oxides, nitrous oxides, ammonia, Sulphur dioxide	Landfilling, composting, Backyard burning and incineration	Ji *et al*63
Smog formation	Nitrogen oxides	Burning of waste	Girish *et al*[64]
Eutrophication	Nitrates, Phosphorus & Nitrogen	Composting and Landfilling leachate	Nhubu *et al*[65]
Reduces pollution, Reduces GHG emissions, Reduces the toxicity of waste, conservation of natural resources and sustains the environment for present and future generations		Reduction of waste	Song *et al*,[66] Hussain *et al*[67]

Reduces the quantity of waste directly going to landfills and reduces the emissions of pollutants. It promotes the conservation of virgin materials.	Recycling	Ragaert *et al*[69]
Prevents pollution, Reduces GHG emissions and minimizes the waste to be recycled or disposed of to landfills and incinerators	Reuse	Liu *et al*,[69] Almasi *et al*[70]

Table 2: Waste streams and associated environmental and health risks

Waste Streams	Pollutants and Threats	Environmental and Health Risks
Open dumping of MSW	Leachate production having significant concentrations of COD and BOD and heavy metals: Ammonia and Sulphates.[71] Emission of landfill gases mainly composed of CH4 and carbon oxides due to the anaerobic decomposition of organic waste.[72] Home to disease vectors	The leachate is released intothe soil, causing soil and groundwater pollution. Health risks arise due to indirect and direct intake of water or through soil.[73] The release of methane and other GHGs causes air pollution and increases global warming.[74] Feeding animals, rodents and insects on dumpsites increases the risk of disease transmission via bites or direct contact with the animals.[75] Uncontrolled disposal leads to the dumping of plastics into rivers, lakes and seas, causing marine littering.
Open Burning of MSW	Release of PCDDs/ PCDFs, PCBs, Particulate Matter, Black Carbons, CO, NO, CO_2, carcinogenic compounds and other GHG gases.[76]	The generation of black carbons, carbon monoxides and dioxides affects Global Warming Potential more than anaerobic digestion.[76,77] Respiratory illness, particularly among children, is commonly observed in areas with open burning of waste.[78]
Biomedical and health waste	Open dumping of infectious and sharp waste Burned waste produces PCDDs, PCDFs and other hazardous compounds.[79,80]	Biomedical waste poses serious risks to waste pickers who come in direct contactwith sharp and infectious waste. They are prone to cuts, injuries and various types of infections.[81,82] Burned medical waste is also a source

		of PCDDs and PCDFs that raises the residents' cancer and respiratory diseases.[83]
E-waste	Electronic waste leachates contain heavy and toxic metal concentrations. Open burning is a source of hazardous compounds like Black Carbon, PCDDs and PCDFs etc.[84,85]	E-waste contains toxic components such as lead, mercury, barium, lithium and cadmium, etc., which negatively affects human health.[86] This waste considerably affects the heart, liver, brain, kidney and skeletal system. It also harms humans' reproductive and nervous systems.[87]
Construction and Demolition Waste	Gives rise to landslides due to open dumping of C&D waste. Contains hazardous materials: asbestos, lead, mercury, chlorine fluoride carbides and other toxic materials.[88,89]	Huge dumps of C& D waste reduce the life and density of disposal lands, giving rise to collapsing and landslides.[90,91] The presence of mercury and lead leads to respiratory, skin and other diseases.[92]
Rubber and tyres Waste	Open dumping attracts mosquitos, flies and insects. Open burning generates toxic gases like black carbons and Sulphur oxide.[93,94]	Open dumping paves the way for diseases like malaria, yellow fever, dengue etc. The presence of highly combustible waste can lead to fires.[95] Open burning induces high concentrations of particulate matter, black carbons and Sulphur oxides increasing the global warming potential and acid rains.[96]
Industrial waste	Hazardous leachate containing heavy metals.[97]	Heavy metals affect the soil and groundwater, harming human health via direct or indirection ingestion.[98]

Major Environmental Impacts and Associated Health Risks of Improper SWM in Developing Countries

Environmental consequences arising from the MSW and its strategies can be positive or negative. These negative and positive outcomes result from either the absence or presence of specific contaminants that unfold over some time. Negative repercussions pose serious health risks for humans and other living organisms. The danger associated with inappropriate MSW disposal and correlated environmental health impacts should be of utmost importance to MSWM experts. The significant environmental effects and public health implications of SWM are discussed as follows:

Conclusions, Suggestions and Policy Implications

The study provides a holistic assessment of solid waste pollution affecting the environment and public health. Many reviews have been published in the scientific literature about solid waste management's environmental and health impact. However, the present research reviews the dominant illegal practices of SWM in developing countries. The study consolidates the specific improper SWM technique, related emissions, associated environmental and health implications in a tabular form for better interpretation, clarity and understanding. The inferences and case studies can be of utmost importance to researchers and other stakeholders in quantifying improper SWM's impact. This comprehensive study reveals the waste stream and disposal technique with the worst environmental and health consequences. Developing countries are found to practice open dumping and open burning of solid waste heavily. These illegal practices are a warning of ecological and health injustice. Solid waste pollution contaminates air, water and soil, affecting human health. People living close to

unsanitary landfills and burning areas are more prone to health jeopardies. The study recommends that government bodies and local authorities shift from a traditional way to a comprehensive scientific disposal method. The Residents should be made aware and convinced to follow the specified waste management hierarchy. Adopting the 3R strategy- Reduce, Reuse and Recycle will reduce the transportation as well as the amount of waste going into the dump yards. Waste to Energy technologies makes the world realize that waste has immense resource potential. Therefore, the proper technologies with individual consciousness will help improve the disposal mechanism and thus mitigate detrimental environmental consequences.

Acknowledgement
The author acknowledge the faculty and research fellows of Department of Economics, University of Jammu, J&K for the presented work.

Funding
No funding

Conflict of Interest
We have no conflict of interest.

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